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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

Donald Abelson
Chief, International Bureau
Federal Communications Commission

Re: Reference NGSO rulemaking ET Docket No. 98-206, RM-9147, and RM-9245

Dear Mr. Abelson:

PanAmSat Corporation ("PanAmSat") hereby submits for the record in the above-referenced proceeding materials that PanAmSat prepared and submitted, through the U.S. Delegation, to the 2000 World Radiocommunication Conference Preparatory Meeting ("CPM") held in Geneva, Switzerland November 15-26, 1999. In addition, PanAmSat has a number of comments and recommendations regarding the resolution of certain GSO and non-GSO ("NGSO") FSS sharing issues, as reflected in Chapter 3 of the CPM Report and the PanAmSat documents submitted to the CPM meeting (copies of the PanAmSat documents are attached). Finally in the attached ANNEX to this letter we provide detailed information that could be used in drafting FCC Rules.

BACKGROUND

The geostationary satellite orbit (GSO) is a unique resource that is shared efficiently by a large number of satellites using a wide variety of frequencies. The GSO enables a variety of communications applications for billions of users worldwide. It is essential that this orbit be protected so that existing and future services can continue to be offered without undo constraint.

A particularly contentious aspect of the ongoing debate since WRC97 has been the controversy between U. S. GSO operators and Intelsat on one side and SkyBridge on the other, regarding the protection criteria that NGSO systems must afford larger-size GSO earth stations operating in the FSS Ku bands. In general, the GSO operators' arguments had been based upon their concerns with the reduction in performance that would result from NGSO interference to GSO systems when sharing use of those frequency bands.

SkyBridge claimed that the resulting interference from their shared use of the spectrum would have a minimal impact on existing GSO systems and that competition from NGSO systems would benefit consumers. They further argued that restrictions on NGSOs proposed by GSO interests would involve extreme expense that would preclude operation of the SkyBridge system.

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The CPM moved towards resolving the sharing issue by putting in place a compromise that included three mechanisms intended broadly to assure that NGSO systems would not unduly interfere with GSO systems. The compromise is intended to assure interference protection for GSO systems by use of validation and operational masks and operational limits.

Simply stated, the three mechanisms for GSO protection are as follows:

1. A "validation mask," representing the worst case statistical interference levels that each NGSO system would be permitted to cause to GSO network earth stations. An administration proposing a NGSO system would have to demonstrate compliance with the validation mask. There would also be a threshold validation test regarding the aggregate amount of interference permitted to a GSO system from all NGSO systems. The validation test for meeting the mask limits would be administered by the ITU Radiocommunication Bureau (BR). The software used to conduct the test would be developed by interested administrations and adopted by the ITU.

2. An "operational mask," representing the maximum statistical interference potential that would be permitted over the operational life of an NGSO system, assuming normal conditions. An administration proposing a NGSO system would be required to certify to the ITU that the proposed NGSO system complies with that operational mask. Individual administrations also could use the operational mask as an eligibility standard for authorizing NGSO systems within their national boundaries.

3. "Operational limits" specifying the maximum levels of interference that NGSO systems would be permitted to cause to specific GSO earth stations. The intention is to establish maximum levels and set them out as criteria in the ITU's Radio Regulations. If a GSO system operator experiences sync loss when the NGSO system exceeds these levels, steps would have to be taken to reduce the interference levels to meet the criteria.

PanAmSat has concerns and recommendations regarding each of these three mechanisms, as set out below.

VALIDATION MASKS

With respect to the NGSO applicant's ITU showing for both the single entry and aggregate validation curves, theU.S. should pursue an outcome at the ITU in which: (1) software will be developed quickly; (2) validation will be part of the initial filing process for NGSO systems; and, (3) full particulars will have to be provided by the applicant at the outset so that interested administrations can verify compliance.

The verification process requires each NGSO administration to supply as an input to the software, a PFD mask defined by the maximum power flux density as seen from any point at the surface of the earth. The FCC should incorporate the single entry validation mask, as well as the PFD mask, into its NGSO space station licensing process so that GSO operators will have a domestic remedy available if interference to their systems results despite the applicant's showing of compliance with the validation mask. Moreover, the FCC should develop and be prepared to administer its own procedures for enforcement of the single entry and aggregate interference standard in both the NGSO space station and gateway earth station licensing proceedings prior to a grant of authority.

OPERATIONAL MASKS

Because a statistical operational mask cannot be verified easily by measurements, the FCC should support the adoption of a software compliance procedure as suggested in the CPM report. That procedure also should require that applicants include the full particulars and assumptions used as the basis for their request for certification.

For its part, the FCC should adopt criteria for operational mask software in its rules and require NGSO space station applicants and gateway earth station applicants to make a showing of compliance and make the software program available to the public, including full particulars (*e.g.*, source code, operational assumptions, etc.). Software verification should include the generation of maps showing maximum NGSO interference power levels that could be received in the U.S., as seen by two-degree spaced GSO space systems that could serve the U.S. In addition, a software tool should be supplied by the applicant, including the source code, that would allow the determination of temporal interference statistics for any location within the U.S. territorial limits.

OPERATIONAL LIMITS

It is essential that the enforcement of any operational limits adopted by the ITU not deteriorate into a long and contentious process. Accordingly, and in order to keep itself from becoming embroiled in protracted interference disputes once NGSO systems are operational, the FCC should require that NGSO space and earth station gateway applicants demonstrate compliance with operational limits at the outset, as part of the license application process. Further, the FCC should institute specific and reasonable procedures that would allow a GSO operator to determine the location of each NGSO satellite and then identify, confirm and obtain relief from an interference complaint. Thereafter, if a GSO system operator can demonstrate that the NGSO system is not in compliance with the limits set out in the FCC rules, the Commission can require compliance.

Respectfully submitted,

Kalpak S. Gude

Kalpak S. Gude
Vice President and Associate General Counsel

ANNEX - Proposed information that should be included but not limited to being required by the FCC Rules

1. Demonstration of meeting the aggregate limit mask

The filing NGSO shall provide documentation demonstrating that they meet the aggregate limits. This may be done by software that calculates $EPFD_{down}$ statistics for prior licensed NGSO systems. Software source code, justifications and assumptions must be included. The software should reflect the assumptions that each NGSO system used for FCC validation.

2. Operational Masks

The NGSO must demonstrate that they will meet the operational masks within the United States. Since NGSO interference will vary geographically and temporally, the filing NGSO shall provide documentation demonstrating that they meet the operational masks for both temporal and geographical distributions. This may be done by software provided by the NGSO applicant. Software source code, justifications and assumptions must be provided.

Since interference into the United States could be caused by traffic to other countries the demonstration should take into account the global operations of the NGSO system.

2.1 Temporal Operational Limit Software

The temporal operational limit should be capable of calculating the $EPFD_{down}$ cumulative probability density function for any specific location within the United States.

The method used in this demonstration should be capable of taking into account the maximum traffic loading distributions and geographic specific scheduling. The NGSO system under consideration will be restricted to operate within the bounds of these input parameters.

Copies of the software used for the demonstration must be filed with the commission so that it can be made publicly available.

2.2 Operational Limit Map Software

A demonstration is to be provided consisting of a set of maps illustrating the geographic distribution of the maximum $EPFD_{down}$ levels within the United States. Any given location on a map will show the maximum $EPFD_{down}$ level that can occur at that location.

The demonstration should take into account the maximum traffic loading distributions and geographic specific scheduling that will meet the operational limits. The NGSO applicant will be restricted to operate within the bounds of these input parameters.

Maps represent specific target GSO longitudes, spaced in 2° increments across the visible GSO arc.

The Maps should output maximum $EPFD_{down}$ levels with a minimum resolution of 1° longitude by 1° latitude and should envelope all $EPFD_{down}$ levels within that area.

Each map should demonstrate that the $EPFD_{down}$ levels are all below the 100% operational limit values.

3 PFD Mask

The NGSO applicant is required to submit to the FCC a maximum per satellite power-flux density mask. The PFD mask is a ground level limit that should never be exceed.

4. Satellite orbital elements

In order to properly measure both the PFD mask and operational limits the NGSO applicant shall regularly publish satellite orbital elements so that the exact location of any satellite in their constellation can be predicted at any time.

INTERNATIONAL TELECOMMUNICATION UNION
RADIOCOMMUNICATION SECTOR

CONFERENCE PREPARATORY MEETING FOR WRC-2000

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PROPOSED CHANGES TO SECTION 3.1.2.3.2 b) OF THE CPM TEXT BASED ON ANALYSIS OF BR SOFTWARE ASSUMPTIONS

1 Recommended modification to the CPM text section 3.1.2.3.2 b)

The following changes to CPM text section 3.1.2.3.2 b) are recommended based on the analysis described in Annex 1 (also see changes to this section in USCPM99/44 and CPM99-2/137).

The introduction of power limits into Article **S22**, to share frequencies with non-GSO FSS systems, represents the acceptance of a burden on the part of the GSO FSS networks: i.e. the establishment now of acceptable interference levels from non-GSO FSS systems into all present and future GSO FSS networks, and the quantification of the protection provided for GSO FSS under No. **S22.2** in the relevant bands.

~~The calculation of the impact of a given $EPFD_{down}$ mask on each link in the CR92/CR116 database has necessarily been based on a combination of significantly conservative assumptions which, for an individual link, has a low probabiity of occurring~~. ~~Also, i~~In order to ensure protection, a number of worst-case circumstances have been assumed in drawing up the specification for the BR compliance verification software.

Taking into account the fact that ~~conservative~~ assumptions have had to be taken, attention is drawn to the following factors:

- The ITU-R analyses were conducted with the aim of protecting as many of the CR92/CR116 links as possible.
- The $EPFD_{down}$ links must be met for every location on the Earth's surface and for any pointing direction towards the GSO. However, any given non-GSO FSS constellation will generate its maximum $EPFD_{down}$ level in only a modest proportion of the Earth's surface. For each earth station location the maximum interference peaks will be relatively infrequent. Nevertheless, $EPFD_{down}$ levels below the maximum may be a problem for some GSO links. Quantification of these factors depends heavily on the characteristics of the non-GSO FSS system.
- ITU-R antenna reference patterns, including the pattern in draft new Recommendation S.[Doc. 4/57], are employed for GSO earth stations, in both the ITU-R analyses and the BR software specification. These reference patterns necessarily err on the side of caution, and in practice the roll-off of the GSO earth station antenna main beam is likely to be rather faster than modelled. Also, in the models of non-GSO satellite antennas used in the analyses, the side-lobe gain assumed is likely to be somewhat higher than reality. These factors lead to conservative estimates of the duration and levels of interference peaks.

- The methodologies used to derive EPFD masks lead to conservative results because the only sources of short-term degradation taken into account are rain fading and non-GSO interference. It is noted that the rain fade models used are long-term averages, and that the rain attenuation varies substantially from year to year.
- The methodologies used to derive the pfd masks that are input into the BR compliance verification software use what is by definition a "worst-case" scheduling algorithm for beam pointing. However, studies have shown that this is a tight bound on the true answer, because more realistic scheduling algorithms, such as pointing in the direction of the cells that result in the highest elevation angle beams, result in EPFD curves that are within 0.3 dB of the worst-case scheduling algorithm.

Reasons: This section of the CPM text asserts that the method used to construct $EPFD_{down}$ masks employs several "significantly conservative" assumptions. The analysis presented in the annex shows that this is not necessarily the case. Accordingly, the proposed modification deletes references to "conservative assumptions" and adds text to emphasize that so-called "worst-case" assumptions can result in interference levels that are quite realistic.

ANNEX 1

1 Introduction

The BR software simulates non-GSO systems assuming a worst-case configuration of all of their beams. This approach was adopted in order to allow the non-GSOs the flexibility to use any scheduling algorithm. It has been suggested that this assumption is an extreme worst case that is unlikely to occur in the actual deployed non-GSO system.

However, this document demonstrates that this worst-case configuration is not that unlikely. The document compares the worst-case scheduling of antenna beams assumed by the BR software with a typical scheduling algorithm.

2 Analysis

FSAT-MULTI 1B was analysed using both a worst-case scheduling algorithm and a highest elevation angle scheduling algorithm. The worst-case scheduling algorithm dynamically chooses 12 beams that would cause maximum level of interference at every time point in the simulation. The highest elevation angle scheduling algorithm chooses 12 beams with the highest corresponding gateway elevation angles. It should be noted that the analyses used a Bessel function approximation for the FSAT-MULTI 1B antenna pattern, since the true pattern was not available.

The analysis simulated 10 000 random locations on the Earth's surface with a corresponding 10 000 random GSO locations. For each location, an EPFD CDF curve was simulated. The curves shown in Figure 1 represent the envelope the EPFD CDFs for all the locations simulated.

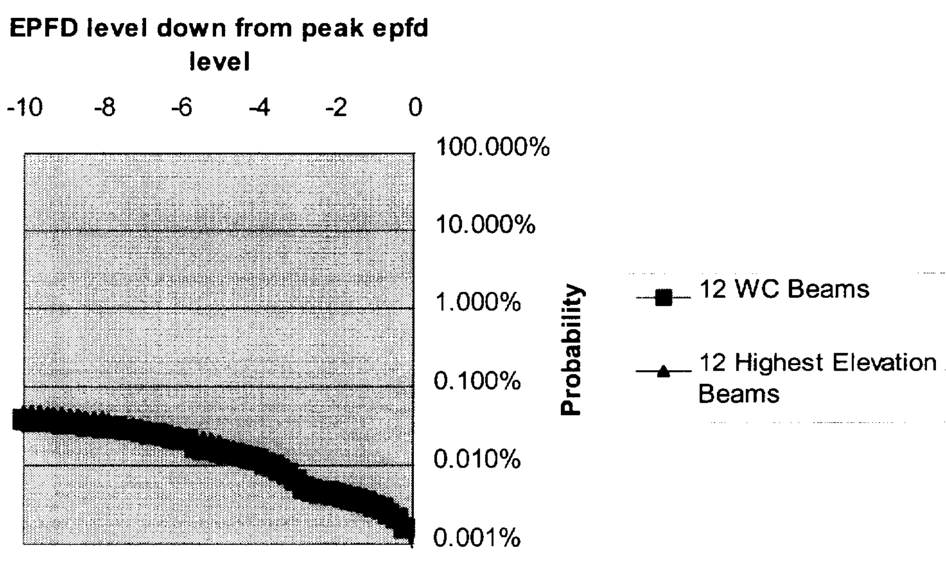

FIGURE 1

EPFD envelope of 12 highest power beams vs. 12 highest elevation angle beams

These curves show that at most there is a 0.3 dB difference between the non-GSO simulation using highest elevation and the non-GSO simulation using the worst-case scheduling algorithm.

3 Conclusion

The BR software method of using the beams that cause the most interference is by definition a worst case. However, this analysis shows that it is a tight bound on the true answer, because the highest elevation angle scheduling algorithm used here is both realistic, and results in EPFD curves that are within 0.3 dB of the worst-case scheduling algorithm.

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INTERNATIONAL TELECOMMUNICATION UNION
RADIOCOMMUNICATION SECTOR

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A STUDY OF THE NUMBER OF POSSIBLE GSO FSS LINK GROUND STATION SYNCHRONIZATION LOSS EVENTS PER YEAR THAT MAY BE CAUSED BY INTERFERENCE FROM NON-GSO SYSTEMS WITH AN FSAT-MULTI 1B CONFIGURATION

1 Recommended modification to the CPM text section 3.1.2.1.2 c)

Accordingly, it is proposed that the following text be added to the end of section 3.1.2.1.2 c) of the CPM text.

Studies have shown that the number of synchronization loss events per year to GSO FSS link earth stations caused by interference from non-GSO systems can be significant.

It is also proposed that section 3.1.2.3.2 c) of the CPM text be changed as follows.

For those individual links which ~~might~~are not ~~be~~ fully protected by the $EPFD_{down}$ masks, various ways of compensating for any shortfall in protection were considered and it was concluded that the most convenient one would usually be an increase in the satellite e.i.r.p. allocated to the GSO link, where feasible. Most of the links in the CR92/CR116 database which the $EPFD_{down}$ masks do not protect according to the 10% criterion are characterized by large earth station antennas and small margins~~, and hence their satellite e.i.r.p.s. are relatively low compared with other links of similar bit rates~~. Therefore the reduction in transponder capacity caused by such e.i.r.p. increases, though representing a burden, could be modest in multicarrier transponder cases. It is noted that it is appropriate for some links to be designed to have small margins. Furthermore, it should be noted that GSO commercial users who implement transponders, lease them on the basis of power and bandwidth. Therefore, it is typical to maximize the utilization of the resource where there would be little additional power available in the transponders to protect against non-GSO interference.

For earth station antennas between 3 and 10 m, depending on coding and link availability, synchronization loss can occur in almost any rain zone due to the non-GSO interference levels represented by EPFD masks (curve A and B). Analyses have shown that many of the links in the CR92/CR116 database will suffer from a large number (several hundred) of synchronization losses per year. The only way to compensate for the sync loss shortfall is by increasing the e.i.r.p. allocated to the GSO link, where feasible.

Reasons: The study described below in this paper documents that large proportion of GSO FSS link earth stations will receive a significant number of synchronization losses per year. Since synchronization losses can cause large amounts of data to be loss before recovery, this effect is particularly significant and should be emphasized in the CPM text. Also, section 3.1.2.3.2 c) should be modified because it asserts that the burden to GSOs caused by interference from non-GSOs is modest. Also see paper CPM99-2/138.

2 Introduction

Recommendation ITU-R S.[Document 4/69] refers to the protection of GSO FSS links from loss of synchronization. The JTG CPM text, section 3.1.2.1.2 c), defines threshold criteria for sync-loss for various modulation schemes and coding rates. However, this text makes no reference to the magnitude of this problem. Therefore, additional text is proposed to do this based upon the following analysis.

3 Analysis

Figures 1 through 6 below show the average and maximum number of times that any spacecraft in the FSAT-MULTI 1B constellation will fly through the main beam of a GSO ground station antenna. For each GSO ground station latitude, 1 000 random values were generated for the longitude difference between the GSO ground station and the GSO spacecraft. The analysis assumes that the FSAT-MULTI 1B constellation has a non-repeating ground track.

It is noted that these results are independent of the antenna characteristic implemented on the non-GSO satellites and the pointing algorithm used. Therefore, the results can be considered as representative of non-GSO system configurations. The study results are summarized by the graphs shown in Figures 1 through 6. An event is considered to have occurred if the satellite passed through the GSO earth station within the 1, 3 or 5 dB beam width of the GSO earth station antenna. Since the number of events is dependent on the proximity of the non-GSO ground tracks, two graphs for each beam width are given. The odd number graphs depict the events for 3, 4.5, 6 and 10 metre antennas at average earth site locations. The even number graphs show the number of events for stations located where they would receive the maximum number.

It can be seen in the graphs that the number of times per year in which an non-GSO satellite passes through the main beam of a GSO ground station antenna is significant, typically several hundred to a few thousand. These in-line events may cause synchronization losses on the down link to a GSO ground station receiver. However, in-line events will not necessarily cause synchronization losses. This phenomena is very system specific in that it depends on the characteristics of the transmit antennas, the antenna pointing algorithms used, and other factors.

In order to quantify synchronization loss, an analysis was performed to determine the number of synchronization loss events per year caused by the FSAT-MULTI 1B constellation vs. the percentage of the Earth's surface affected. Sync loss was considered to occur whenever the EPFD levels shown below in Table 1 were exceeded. It should be noted that this was a complete analysis that took communications parameters into account. A full simulation was run for 10 000 randomly chosen GSO earth station locations. Each simulation determined the interference levels received (and the number of times this levels exceed the threshold per year) by taking into account space loss between the interfering non-GSOs and the victim GSO ground stations and the gains due to antenna off-pointing of both the transmit and receive antennas. Table 1 is taken from CPM99-2/138. The results of this analysis are shown in Figure 7. It can be seen that several hundred sync loss events occur over a significant percentage of the Earth's surface.

TABLE 1

Epfd levels required to protect against sync. loss

Antenna diameter (m)	System temperature (K)	Sync. loss threshold ($dBw/m^2/40$ kHz)
3.0	350	-163
4.5	450	-165
6.0	600	-166
10.0	800	-169.5

The results displayed in Figure 7 also support CPM99-2/89, MOD 3.1.2.1.2 c), which states that "the number of yearly sync-loss occurrences caused by in-line events is greater than those induced by rain".

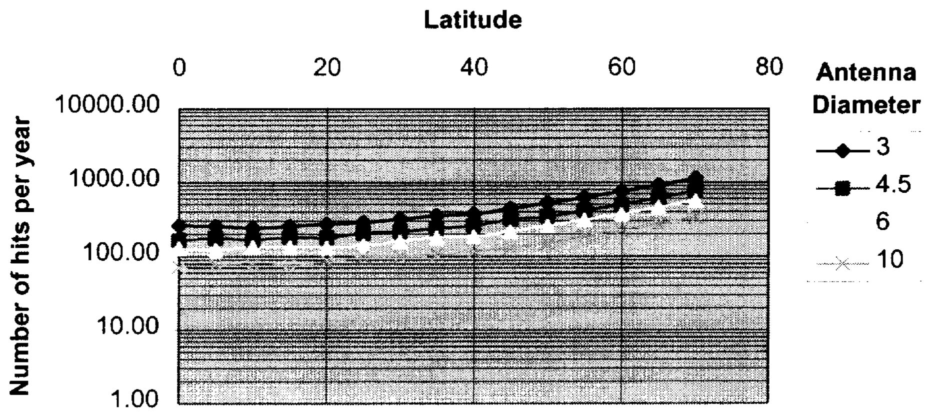

FIGURE 1

1 dB beamwidth, average

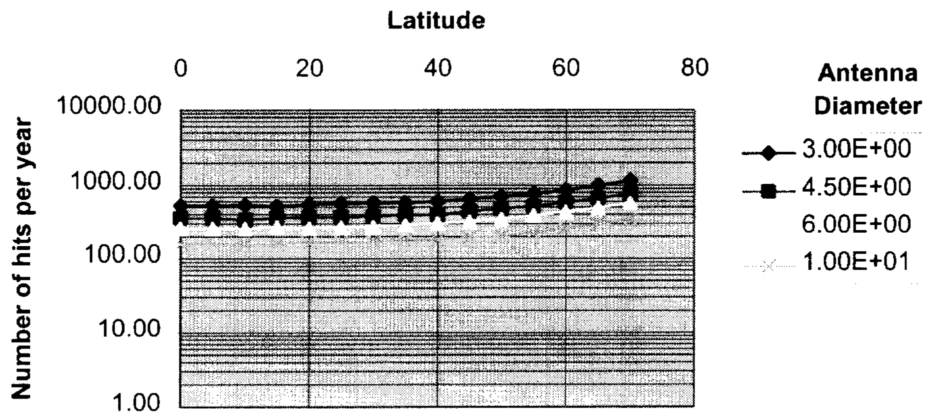

FIGURE 2

1 dB beamwidth, maximum

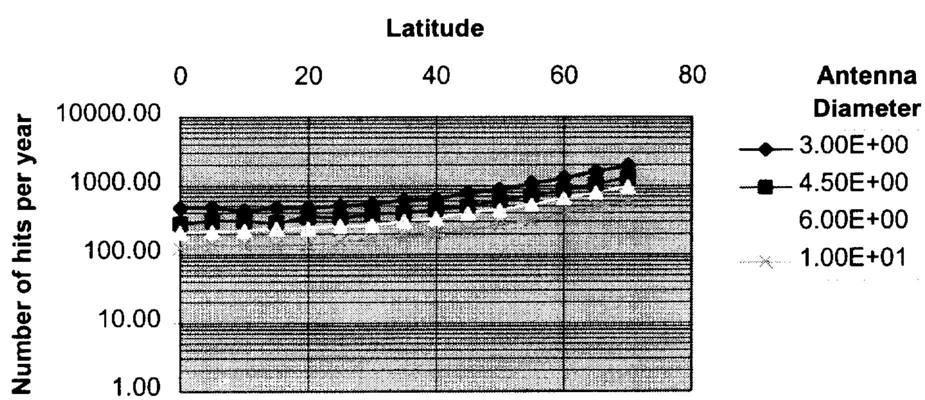

FIGURE 3

3dB beamwidth, average

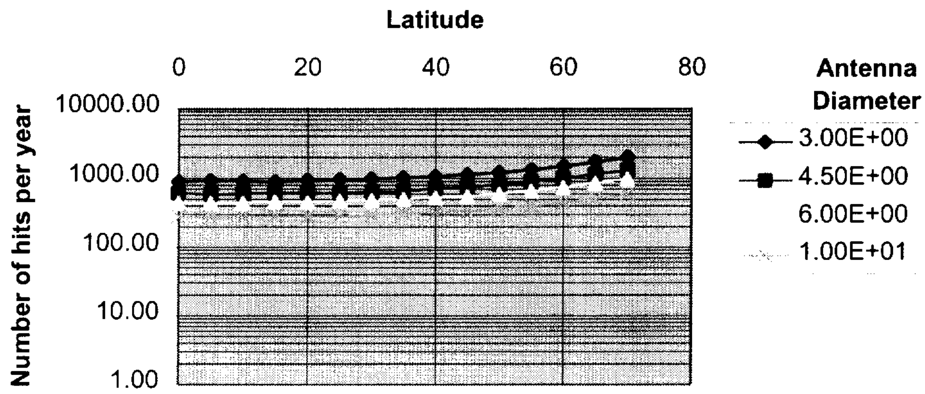

FIGURE 4

3 dB beamwidth, maximum

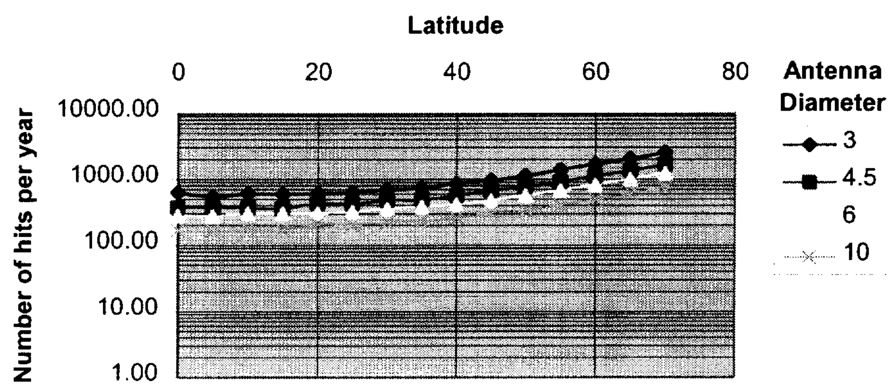

FIGURE 5

5 dB beamwidth, average

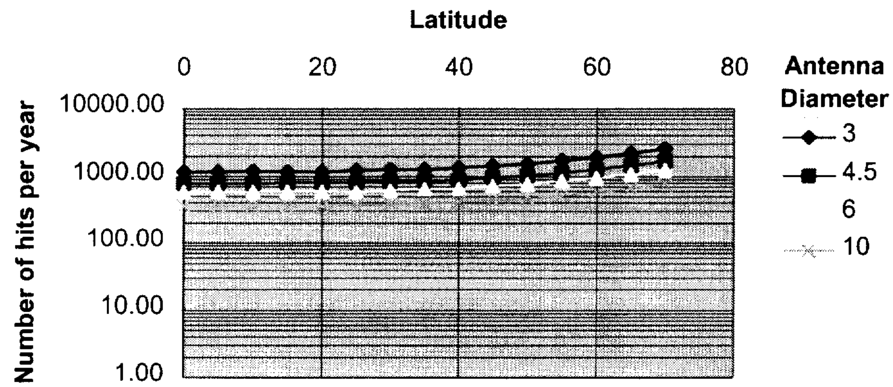

FIGURE 6

5 dB beamwidth, maximum

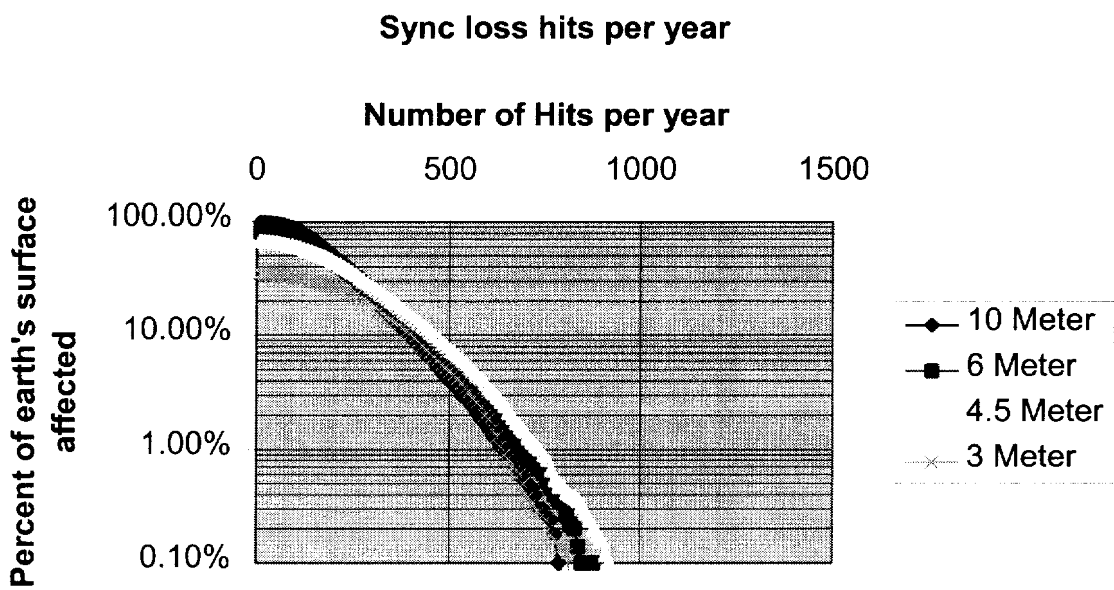

FIGURE 7

Sync loss hits per year

INTERNATIONAL TELECOMMUNICATION UNION
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AN ANALYSIS OF F-SAT-MULTI-1B INTERFERENCE TO GSO GROUND TERMINAL EPFD LEVEL DISTRIBUTIONS AND PROPOSED MODIFICATIONS TO SECTIONS 3.1.2.4.6 AND 3.1.5.1 OF THE CPM TEXT

1 Recommended modification to the CPM text section 3.1.2.4.6

The following changes to CPM text section 3.1.2.4.6 are proposed based on the analysis described in the Annex:

b) definition of additional required input information by modification of Appendix **S4** or another method, and Bureau examination of input data and the program used to generate the input data for correctness and completeness before the data is used as software input. <u>Administrations should be required to submit any needed information relevant to the mask generation at the request of the BR.</u> Procedural work will be necessary to distinguish between "incorrect or incomplete information" and other changes in the system;

Reasons: The analysis described below in the Annex is an example that illustrates the danger of making a simplifying assumption: that spacecraft that use "sticky" beams can be accurately modelled with "sweeping" beams. It is shown that the results can vary significantly between the two models. The only way to ensure that a system is modelled completely and correctly is for administrations to supply all input data and the programs used in generating the masks. These changes are also consistent with modifications to the BR Software Functional Description approved by JWP 10-11S in Document 10-11S/TEMP/125, sections 2 and 3.

ANNEX

1 Introduction

Engineers employed by F-SAT-MULTI-1B have run analyses in which their input pfd/e.i.r.p. mask was developed using the simplifying assumption that the antenna beam centres move with the spacecraft (sweeping beams). However, in actuality F-SAT-MULTI-1B satellites will continually point at a fixed location while compensating for the satellite travel (sticky beam). This approximation may not have a significant impact on determining the maximum EPFD levels using the BR evaluation software in the form being considered. However, it can have a significant impact in determining how those maximum levels are geographically distributed. This is an important consideration when evaluating latitude EPFD compliance requirements.

This deviation points out the complexity in judging compliance of non-GSO systems. It also points out that the compliance procedure must take into account the detailed operation of the non-GSO operating scenarios to that the pfd/e.i.r.p masks provide an accurate representation of the non-GSO system.

2 Analysis

This document demonstrates the effect of assuming a sweeping beam scenario on EPFD levels by analysing the geometric distribution of maximum EPFD levels for F-SAT-MULTI-1B first assuming the gateway cells are fixed on the ground; and, second making the simplifying assumption that the cells move with the spacecraft.

An analysis was performed to determine in line EPFD levels for various locations on the Earth. Where in-line EPFD level is defined as the EPFD level when a non-GSO spacecraft passes through the main beam of the GSO ground station. This analysis uses the non-GSO antenna pattern described in section 2.2.1.3.2 of Document WP 4A/58.

Figure 1 shows in-line levels assuming a fixed pattern of non-GSO gateway cells separated by 700 km. The banding effect is due to the switching on and off of beams to gateways when they move in and out of the non-GSO exclusion zone. As a cell gets closer to the exclusion zone (due to the movement of the non-GSO) the EPFD levels increase. (This is because the angle off the non-GSO boresight to the GSO ground station will decrease.) Once the cell reaches the exclusion zone, the beam switches off and EPFD levels drop. That is why the bands appear to be separated by distance between cells. Obviously, the exact locations of these bands are highly dependent on the locations of the gateway cells.

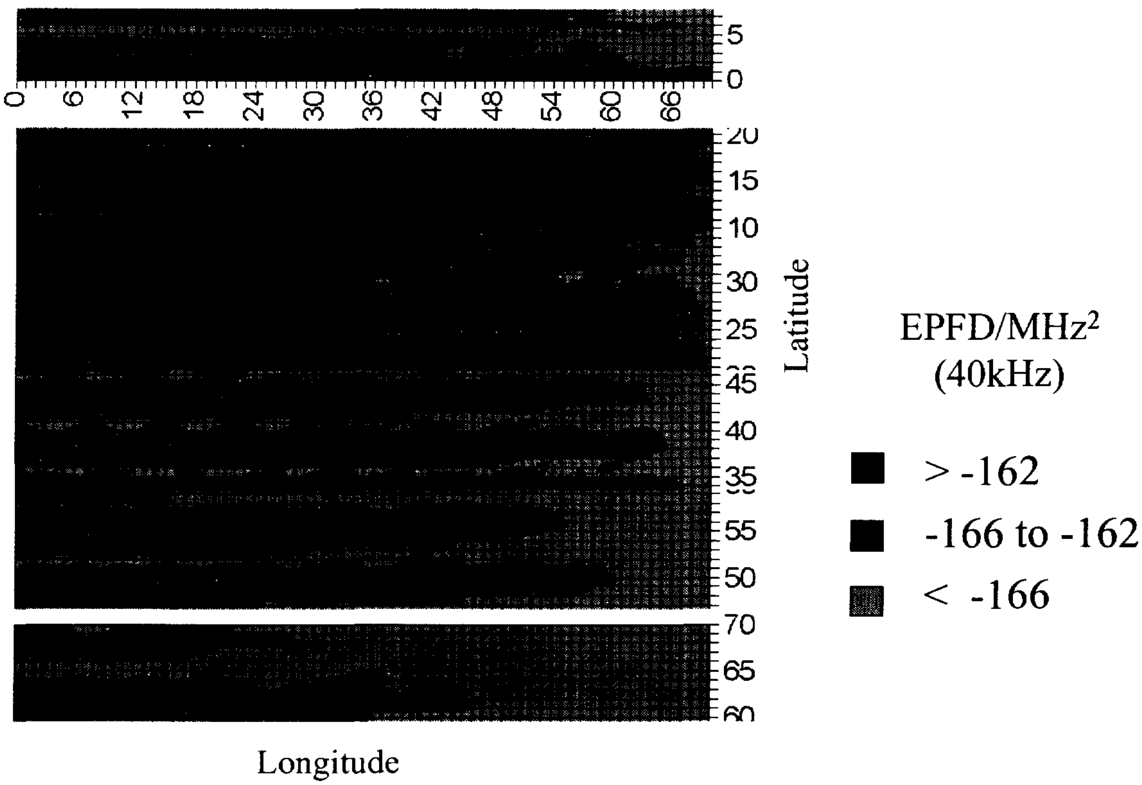

FIGURE 1

In-line maximum EPFD levels of F-SAT-MULTI-1B for fixed cells on the ground.
The latitudes and longitudes refer to the location of the GSO ground station.
The graph assumes that GSO is at 0° longitude.

Figure 2 shows in-line levels assuming a pattern of cells moves with the non-GSO. Notice the bands are much wider apart. As the non-GSO moves up in latitude the angle off nadir to the in-line GSO ground station increases. As this angle increases, cells are switched on and off again due to the relative movement of the exclusion zone. However, instead of the banding occurring every 700 km, the bands occur when an angular cell is turned off. This occurs much less often.

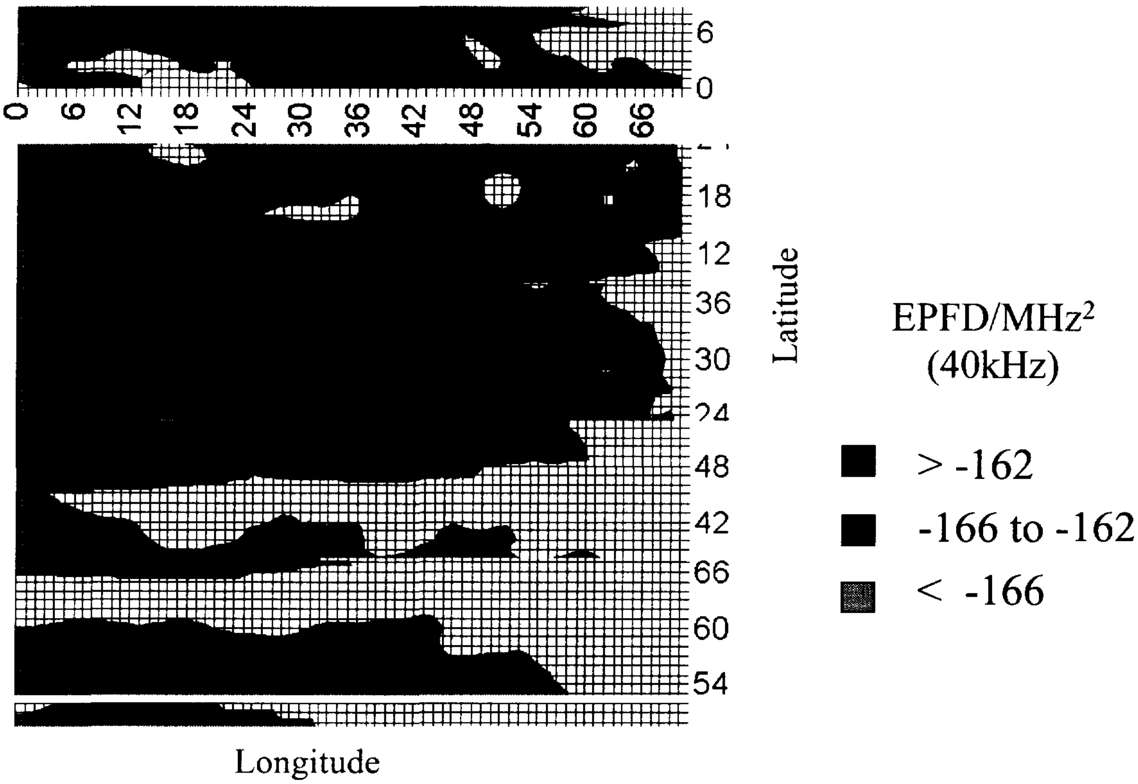

FIGURE 2

In-line maximum EPFD levels of F-SAT-MULTI-1B for fixed cells with respect to the non-GSO spacecraft. The latitudes and longitudes refer to the location of the GSO ground station. The graph assumes that GSO is at 0° longitude.

Notice with this assumption there are large gaps in the EPFD levels. For example, in Figure 2 there are no EPFD levels above -172 dBW for latitudes greater than 60°. However, there is a large area in Figure 1 above 60° in latitude that has these levels.

4 Conclusion

The BR software was specifically designed to determine the EPFD cumulative density function (CDF) for the worst-case location on the Earth's surface. Depending on assumptions made by the non-GSO the geographic distribution of EPFD levels can vary dramatically. The above example demonstrates that complete modeling information of non-GSO scenarios is required in order to assure complete compliance.

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PROPOSED CHANGES TO SECTION 3.1.2.3.2 b) OF THE CPM TEXT BASED ON ANALYSIS OF ENVIRONMENTAL AND OTHER EFFECTS ON NON-GSO ANTENNA SIDE-LOBE LEVELS

1 Recommended modification to the CPM text section 3.1.2.3.2 b)

The following changes to CPM text section 3.1.2.3.2 b) is recommended based on the analysis described in Annex 1 (also see changes to this section in USCPM99/44 and USCPM99/79):

The introduction of power limits into Article **S22**, to share frequencies with non-GSO FSSS systems, represents the acceptance of a burden on the part of the GSO FSS networks: i.e. the establishment now of acceptable interference levels from non-GSO FSS systems into all present and future GSO FSS networks, and the quantification of the protection provided for GSO FSS under No. **S22.2** in the relevant bands.

~~The calculation of the impact of a given EPFD~~$_{\text{down}}$ ~~mask on each link in the CR92/116 database has necessarily been based on a combination of significantly conservative assumptions which, for an individual link, has a low probabiity of occurring. Also, i~~In order to ensure protection, a number of worst-case circumstances have been assumed in drawing up the specification for the BR compliance verification software.

Taking into account the fact that ~~conservative~~ assumptions have had to be taken, attention is drawn to the following factors:

- The ITU-R analyses were conducted with the aim of protecting as many of the CR92/CR116 links as possible.
- The EPFD$_{down}$ links must be met for every location on the Earth's surface and for any pointing direction towards the GSO. However, any given non-GSO FSS constellation will generate its maximum EPFD$_{down}$ level in only a modest proportion of the Earth's surface. For each earth station location the maximum interference peaks will be relatively infrequent. Nevertheless, EPFD$_{down}$ levels below the maximum may be a problem for some GSO links. Quantification of these factors depends heavily on the characteristics of the non-GSO FSS system.
- ITU-R antenna reference patterns, including the pattern in draft new Recommendation ITU-R S.[Doc. 4/57], are employed for GSO earth stations, in both the ITU-R analyses and the BR software specification. These reference patterns necessarily err on the side of caution, and in practice the roll-off of the GSO earth station antenna main beam is likely to be rather faster than modelled. Also, in the models of non-GSO satellite antennas used in the analyses, the side-lobe gain assumed is likely to be somewhat higher than reality. These

factors lead to conservative estimates of the durations and levels of interference peaks for long term (low EPFD level) interference.

- The highest $EPFD_{down}$ levels are expected to be caused by the non-GSO satellite antenna side lobes. Non-GSO systems typically use phased array antennas. Side-lobe levels for these antennas vary over the anticipated life of the non-GSO satellite due to element failures and phase and amplitude errors. These errors tend to increase and change the pointing directions of side lobes. These variations can be taken into account. Error budgets for the antenna can be provided and a mask representing a confidence that these side lobes will not be exceeded can be developed. The BR software indicates that "it is expected that the parameters used to generate the pfd/e.i.r.p. mask correspond to the performance of the non-GSO satellite over its anticipated lifetime". However, no procedures have been developed for taking these factors into account.
- The methodologies used to derive EPFD masks lead to conservative results because the only sources of short-term degradation taken into account are rain fading and non-GSO interference. It is noted that the rain fade models used are long-term averages, and that the rain attenuation varies substantially from year to year.

Reasons: Aging effects can significantly affect the performance of non-GSO antennas and need to be taken into account. The BR software indicates that the parameters used to generate the pfd/e.i.r.p. mask must take into account the performance of the non-GSO satellites over their anticipated lifetime. However, a procedure currently does not exist to do this.

ANNEX 1

Proposed changes to section 3.1.2.3.2 b) of the CPM text based on analysis of environmental and other effects on non-GSO antenna side-lobe levels

Introduction

The evaluation or prediction of the performance of phased array antennas in the presence of elemental excitation variations (due to environmental factors including failures) is an important part of the engineering effort in the development of high-performance antennas for in-orbit operation. As part of the engineering process error budgets are constructed to bound the performance of the antenna over the life of the satellite.

This paper demonstrates the impact of random errors (amplitude, and phase) on a phased array similar to the one used by FSATMULTI-1B. Additionally, the effect of elemental failures on sidelobe performance is shown. This paper demonstrates that these environmental factors can cause large variations in the antenna pattern. It is therefore, necessary to take these factors into account in assessing the impact of non-GSO interference on GSO FSS systems. If these factors are not taken into account then interference from non-GSO systems can be significantly higher than the compliance software will show.

Amplitude and phase error budgets

Each component in an antenna has performance variations with manufacturing tolerance, temperature, frequency, and end-of-life (EOL). In addition, some digitally controlled devices may suffer quantization errors. A typical blank budget for showing amplitude or phase variations are shown in Table 1 below. Depending on the antenna architecture, contributors might be added or deleted.

TABLE 1

Typical budget skeleton, showing amplitude or phase errors, for a phased array

Contributor	BOL	Temperature	Frequency	EOL
RF power distribution RSS total • Column divider • Row divider • Transition				
RF electronics RSS total • Transition • Phase shifter • Driver amplifier • Final amplifier • Amplifier load pull • Power supply variation • Transition				
Passive microwave RSS total • Filter • Polarizer • Radiating element				
RSS grand total				
BOL = beginning of life EOL = end of life				

The BOL values represent variations in gain or phase among paths through the array that exist after manufacture and calibration. The temperature variations are usually diurnal. The frequency variation is sometimes averaged by weighting over the frequency band. The EOL effects are caused by aging effects of electronic devices and the power supply.

Antenna simulation without errors

For this part of the analysis an array antenna model was constructed based on antenna patterns shown in the SkyBridge FCC filing of 8 January 1999. The antenna aperture was sized by the smallest SkyBridge beam scanned 50 degrees from the subsatellite point. All the elements are used for the smallest beam. However only a subset of elements are used for other beams. To match the side-lobe levels in the filing the initial aperture distribution was generated assuming three amplifier levels (0, -3 and -6 dB). Figure 1 shows the aperture distributions for the beam at the subsatellite point and the beam scanned 50 degrees. The shaded elements are used.

		-6 dB	-6 dB	-6 dB	-6 dB	-6 dB	-6 dB	-6 dB	-6 dB	-6 dB	-6 dB		
	-6 dB	-6 dB	-6 dB	**-3 dB**	**-3 dB**	**-3 dB**	**-3 dB**	**-3 dB**	**-3 dB**	-6 dB	-6 dB	-6 dB	
-6 dB	-6 dB	-6 dB	**-3 dB**	**-3 dB**	**-3 dB**	0 dB	0 dB	**-3 dB**	**-3 dB**	**-3 dB**	-6 dB	-6 dB	-6 dB
-6 dB	-6 dB	-6 dB	**-3 dB**	**-3 dB**	**-3 dB**	0 dB	0 dB	**-3 dB**	**-3 dB**	**-3 dB**	-6 dB	-6 dB	-6 dB
	-6 dB	-6 dB	-6 dB	**-3 dB**	**-3 dB**	**-3 dB**	**-3 dB**	**-3 dB**	**-3 dB**	-6 dB	-6 dB	-6 dB	
		-6 dB	-6 dB	-6 dB	-6 dB	-6 dB	-6 dB	-6 dB	-6 dB	-6 dB	-6 dB		

50° Scanned Beam

		-6 dB	-6 dB	-6 dB	-6 dB	-6 dB	-6 dB	-6 dB	-6 dB	-6 dB	-6 dB		
	-6 dB	-6 dB	-6 dB	-3 dB	-3 dB	**-3 dB**	**-3 dB**	-3 dB	-3 dB	-6 dB	-6 dB	-6 dB	
-6 dB	-6 dB	-6 dB	-3 dB	-3 dB	**-3 dB**	0 dB	0 dB	**-3 dB**	-3 dB	-3 dB	-6 dB	-6 dB	-6 dB
-6 dB	-6 dB	-6 dB	-3 dB	-3 dB	**-3 dB**	0 dB	0 dB	**-3 dB**	-3 dB	-3 dB	-6 dB	-6 dB	-6 dB
	-6 dB	-6 dB	-6 dB	-3 dB	-3 dB	**-3 dB**	**-3 dB**	-3 dB	-3 dB	-6 dB	-6 dB	-6 dB	
		-6 dB	-6 dB	-6 dB	-6 dB	-6 dB	-6 dB	-6 dB	-6 dB	-6 dB	-6 dB		

On-Axis Beam

FIGURE 1

Aperture distribution for the beam at the subsatellite point and a 50° scanned beam

Figures 2 and 3 are the antenna patterns generated by the aperture distributions in Figure 1 assuming that there are no errors in the pattern. Figure 4 shows the same patterns as provided in the FCC filing. There appears to be good agreement between the two models.

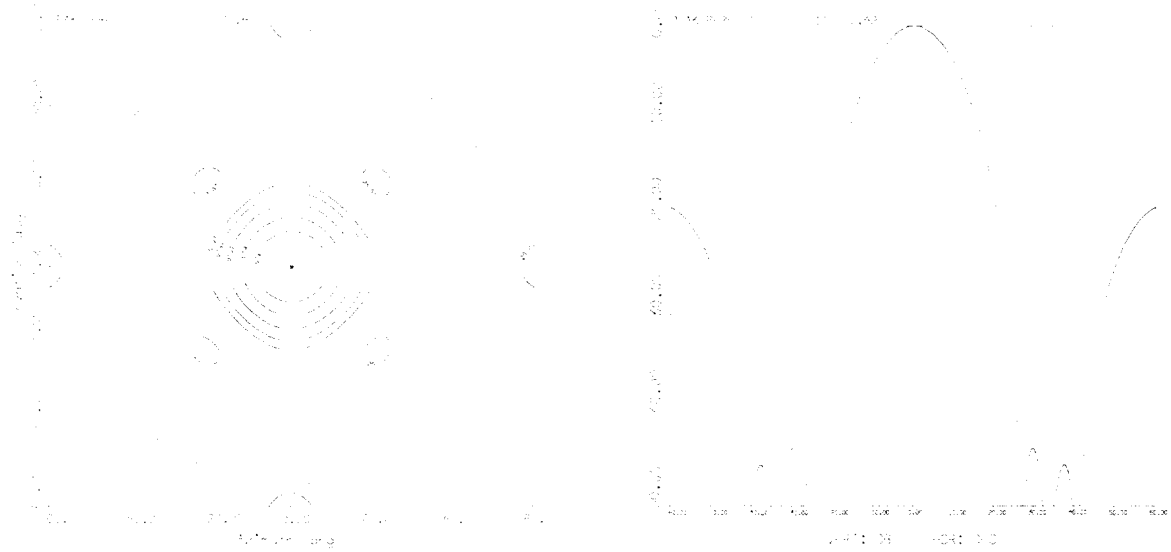

FIGURE 2

Modelled 14 GHz on-axis beam with no errors

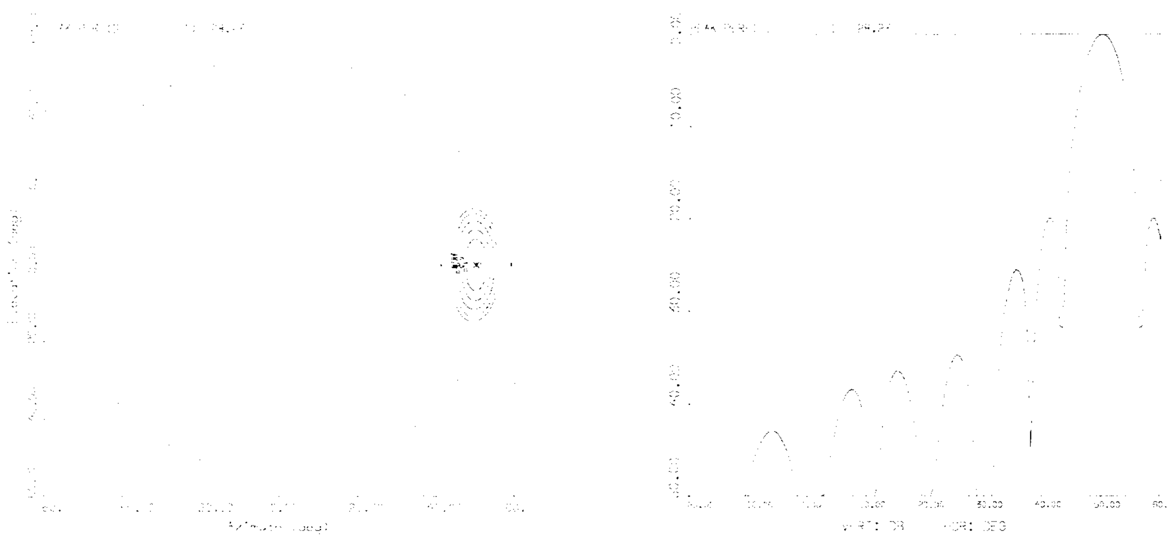

FIGURE 3

Modelled 14 GHz 50° scanned beam with no errors

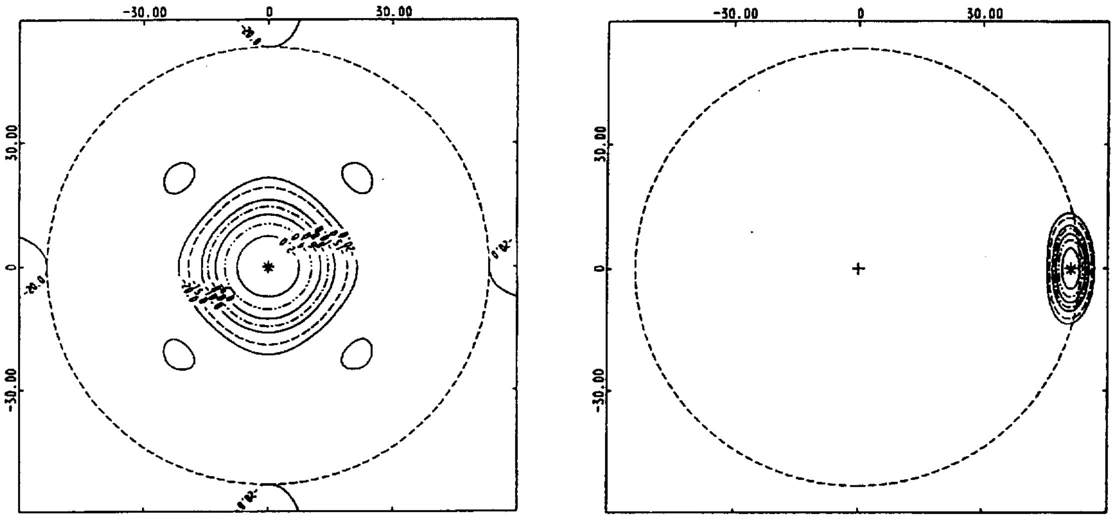

FIGURE 4

Subsatellite and edge of footprint beam from SkyBridge FCC filing

Error impacts on the antenna pattern

The amplitude and phase variations are modelled as Gaussian distributed random errors. The standard deviation of each is listed in the error budget. The failing elements are distributed randomly throughout the array. The total error standard deviation is usually calculated by taking the square root of the sum of the error variances. This assumes that individual contributors are uncorrelated.

It can be shown that the error statistics are described by a modified Raleigh (sometimes called a Rician) probability distribution function. This modified Raleigh was applied to the error-free antenna patterns shown in Figures 2 and 3. Figure 5 shows the antenna patterns when 3% of the elements fail and the standard deviation of the amplitude and phase errors are 1 dB and 10 degrees, respectively. The patterns represent the 99% confidence level when errors are present. These results indicate that the side-lobe performance of a phased array antenna can be much worse when amplitude and phase errors and elements failures are taken into account.

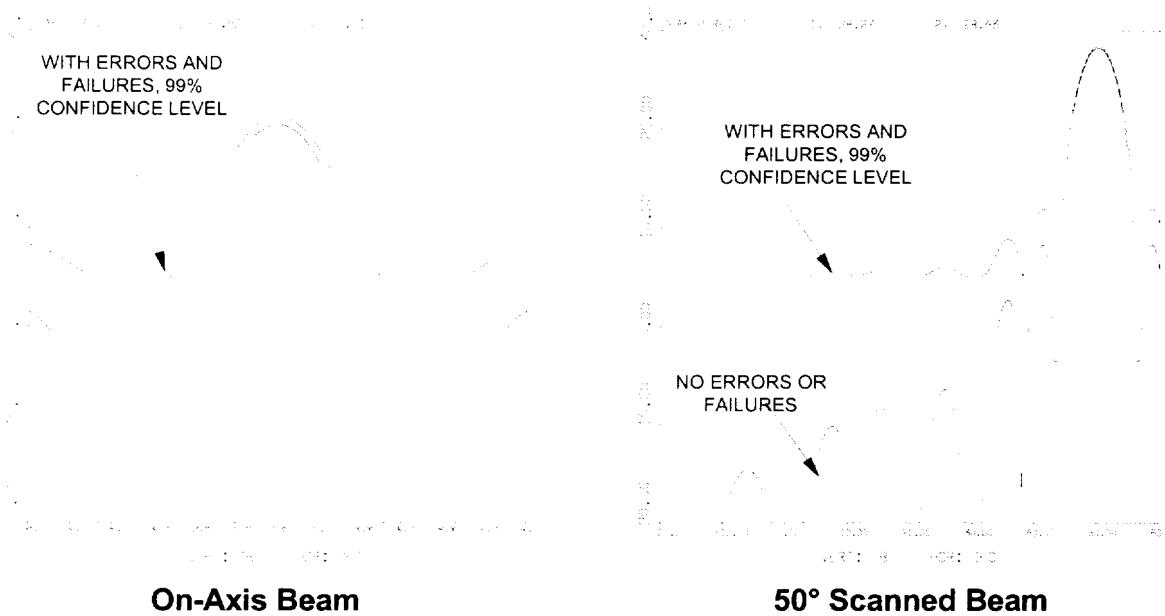

FIGURE 5

99% confidence level, for the modelled FSATMULTI-1B transmit antenna pattern, when errors are present
(Failures = 3%; Amplitude std. = 1 dB; Phase std. = 10°)

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